MASTER'S THESIS

Effects of Structured and Unstructured Collaboration on Collaborative Inquiry-Based Learning in Early Elementary Students.

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Effecten van Gestructureerd en Ongestructureerd Samenwerken
op Collaboratief *Inquiry-Based Learning* bij
Jonge Basisschoolleerlingen

Effects of Structured and Unstructured Collaboration
on Collaborative Inquiry-Based Learning in
Early Elementary Students

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Master Onderwijswetenschappen

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Preface

Before you lies my master thesis ‘Effects of Structured and Unstructured Collaboration on Collaborative Inquiry Based Learning in Early Elementary Students’, which concludes my master’s in education at the Open Universiteit. I conducted my research at the European School Mol in Belgium, the school where I have been working as a teacher in the Dutch section since September 2012.

Students from the second grade of primary school engaged in inquiry-based science lessons and studying their collaboration process helped me to answer my research questions. Collaborative learning is a topic in education that has my interest since many years, because I experience as a teacher how collaboration helps my students to be engaged in their learning process and to learn from each other. The research process was difficult, and it was not always easy to combine this with a fulltime job and family life, but it was rewarding and interesting to see how much the students enjoyed the lessons and to analyse the data obtained in the process. My research gave me new insights into science- and collaborative learning.

I would like to thank my supervisors, Dr. Esther Tan and Prof. Dr. Marcus Specht for their guidance and support during this process. Dr. Esther Tan has supervised my thesis from the beginning. She guided me through the whole research process, taught me how to conduct qualitative research and always gave good suggestions regarding useful and interesting literature.

I would also like to thank my colleagues, the students, their parents and the management of the European School Mol. Not only was I given the opportunity to conduct my research at this school, but my colleagues have been very understanding and very helpful and the students participated in the lessons with enthusiasm. A special word of thanks goes to my colleague Fenny Heemstra, who taught the science lessons in this study and who helped me with the qualitative analysis.

Finally, I would like to thank my boyfriend Niels, who supported me with love and understanding through the whole process. And my parents, my parents in law, and my sister in law who helped taking care of our little sunshine Floor, giving me time to work on my thesis.

I couldn’t have completed my thesis without the support of all these wonderful people. Thank you so much.

I hope you enjoy reading my thesis.

Maria C.J.H. Geurts

Hapert, April 19, 2019

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Summary

Effects of Structured and Unstructured Collaboration on Collaborative Inquiry Based Learning in Early Elementary Students

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Young children's curiosity makes them natural inquirers, yet little research on inquiry-based learning (IBL) has been performed on early elementary students. IBL is an educational strategy in which students acquire knowledge by asking questions, observing and/or conducting experiments, like real scientists. Young children need guidance and scaffolding when engaging in IBL. Collaborating with peers is an effective way to provide scaffolding. Felder & Brent (2007) stress the importance of individual accountability and positive interdependence when students collaborate, in order to avoid social loafing, meaning that not all students participate equally. This can be achieved by structuring the collaboration process by means of a collaboration script (Dillenbourg, 1999).

The purpose of this study was to investigate the effects of structured and unstructured collaboration on collaborative IBL in early elementary students. The overarching research question and a review of the literature in this field culminated in the hypotheses that structured collaboration leads to a better recall of declarative knowledge, a better procedural knowledge of scientific inquiry processes and a higher quality of group discourse than unstructured collaboration.

This study examined a sample of (n = 40) early elementary students of the European School Mol participating in two 45-minute IBL lessons on gravity and air resistance. A mixed method study was conducted to test the hypotheses. Using a quasi-experimental study, the students were randomly put into two experimental conditions: structured- and unstructured collaboration. The collaboration process in the intervention group was scripted using turn taking cards with sentence starters, and interaction rules. Students in the control group received the sentence starters, but no instructions on turn-taking or interaction rules.

The effects of structured and unstructured collaboration on collaborative inquiry-based learning were measured using both quantitative and qualitative data. Quantitative data, pre- and post-test scores on the lesson content and the *Science Learning Assessment* (Samarapungavan, Mantzicopoulos, Patrick, & French, 2009) were collected to measure the effect on declarative and procedural knowledge. The effect on the quality of group discourse was measured with a qualitative analysis and was compared through the level of transactivity, which refers to how peers build on each other's reasoning.

The results of this study showed no significant effect of the condition on declarative or procedural knowledge. Regarding the effect on the quality of group discourse, the control group outperformed the intervention group, as findings indicated a higher level of transactivity in the control group.

The results of this study are not consistent with most studies on structured and unstructured collaboration found in the research literature. A possible explanation for the outcome of this study could be the young age of the participants. Most studies found in the research literature are performed with older students. Younger students might benefit from another approach to collaborative learning than older students. Another explanation could be over-scripting (Dillenbourg, 2002), which can influence the richness of group discourse as the natural collaboration processes between students are affected owing to the structuredness of the script that leads to decreased student motivation. A different degree of structuredness might be more effective for young students.

Keywords: inquiry-based learning, collaborative learning, structured collaboration, collaboration scripts, science learning, early elementary students

1. Introduction

Why is snow cold? Why do leaves turn red in autumn? Where do babies come from? Young children spontaneously ask questions all day long (Lonka, Hakkarainen, & Sintonen, 2000). A survey by British retailer Littlewoods concluded that young children ask about 300 questions a day ("Mothers asked nearly 300 questions," 2013). Their curiosity makes them natural inquirers; yet little research on inquiry-based learning (IBL) has been performed on young elementary students (Howitt, Lewis, & Upson, 2011; Jirout & Zimmerman, 2015).

IBL is an educational strategy in which students acquire knowledge by asking questions, making observations and/or conducting experiments, like real scientists (Pedaste et al., 2015). Through IBL students not only expand their knowledge, but also learn to understand scientific concepts and methods (Bell, Urhahne, Schanze, & Ploetzner, 2010). IBL finds its roots in the work of John Dewey, who argued that science education should teach students to think and act like scientists (Lazonder & Harmsen, 2016).

Many studies in the previous years showed a positive effect of IBL on student learning (Pedaste et al., 2015) and many inquiry-based curricula have been designed for older students as they are considered more receptive to this instructional approach (Wolf & Laferriere, 2009). However, in the last couple of years several studies on IBL conducted with younger students, showed that they are also able to develop science skills, such as questioning, predicting, observing, using scientific tools, recording and communicating results (Howitt et al., 2011; Kim et al., 2012; Marian & Jackson, 2016; Samarapungavan, Mantzicopolous, & Patrick, 2008; Varma, 2014). Critique on IBL comes from Kirschner, Sweller, and Clark (2006), who argue that minimal guidance during instruction, as they identify as a possible risk of IBL, demands too much from the working memory of students, making it a less effective strategy than guided instruction. Hmelo-Silver, Duncan, and Chinn (2007) reply that with scaffolding and teacher guidance, IBL can be a very effective instructional approach.

One way to provide scaffolding is to have students collaborate with their peers (Ge & Land, 2003). Collaboration between students is important for the success of IBL (Hmelo-Silver et al., 2007). Interacting with peers and verbalizing their reasoning helps students to understand new information and to expand their knowledge (De Jong, Kollöffel, Van der Meijden, Kleine Staarman, & Janssen, 2005; Lonka et al., 2000) and students who learn together, will eventually be able to apply the things they have learned individually (De Jong et al., 2005).

However, collaboration does not spontaneously occur when students are placed in groups and are told to work together (Wang, 2009). Collaborative learning is neither a methodology nor a mechanism, but rather, a learning situation where the desired patterns of interaction can only occur by orchestrating the collaboration process (Dillenbourg, 1999). When students are not guided in their collaboration process, collaboration becomes ineffective (Saab, Van Joolingen, & Van Hout-Wolters, 2007).

Collaboration could then lead to social loafing, meaning that some students are not participating nor contributing, while others are doing most of the work (Veenman, Kenter, & Post, 2000).

Collaboration between students only has a positive effect on student learning under certain conditions (Dillenbourg, Baker, Blaye, & O'Malley, 1996). These conditions encompass individual accountability and positive interdependence (Felder & Brent, 2007). Individual accountability means that every group member is responsible for their contribution (Wang, 2009). Positive interdependence means that group members need each other to complete the task and reach their goals (Slavin, 2015). Weinberger, Ertl, Fischer, and Mantle (2005) stress the importance of equal and alternating turns for a successful interaction between collaborating students. Teachers need to structure and scaffold the collaboration process to ensure that desired patterns of interactions occur by giving students specific roles and/or by means of collaboration scripts (Dillenbourg, 1999; Kollar, Fischer, & Slotta, 2007, Weinberger et al., 2005).

Most available research on collaborative IBL includes the use of ICT to foster collaboration and has been conducted on older students. The purpose of this study is to investigate the effects of structured and unstructured collaboration on collaborative IBL with early elementary school students. This study advances existing research because of the focus on early elementary students, which is an under-researched area in the field of collaborative IBL.

IBL and collaborative learning are both instructional strategies which help prepare children for growing up in the 21st century. It is important for educators to adapt their teaching to the needs of students of this generation. Being able to collaborate with others and being able to solve problems by asking questions and finding ways to answer these questions are important 21st century skills. Investigating how to make collaborative IBL effective with young students can help teachers to provide their students with these skills-sets.

The next subsections describe the inquiry process and how to scaffold this process for young students. Collaboration in IBL and structuring collaboration are discussed, leading to the research questions and hypotheses.

1.1 Inquiry-Based Learning and the Inquiry Cycle

IBL falls under the umbrella of constructivism (Oguz-Unver & Arabacıoğlu, 2014). Constructivists believe that students create new knowledge through experience, give meaning to their learning and are actively involved in their own learning process (Ertmer & Newby, 2013). In IBL, students are involved in their learning process and discover new knowledge by asking deductive questions (Oguz- Unver & Arabacıoğlu, 2014) or generating hypotheses and testing them through experiments or observations (Pedaste et al., 2015). From a cognitive point of view, there is no difference between using inquiry for producing new knowledge and using inquiry for learning and understanding new knowledge, which makes inquiry an effective strategy for science education (Hakkarainen & Sintonen, 2002; Lonka et al., 2000). “An inquiry-based learning environment encourages opportunities for children to learn science, learn to do science, and learn about science” (Cuevas, Lee, Hart, & Deaktor, 2005, p. 338). Many studies in the last decades showed a positive effect of IBL on student learning. A meta-analysis of 61 studies by Schroeder, Scott, Tolson, Huang, and Lee (2007) concludes that IBL has a positive effect on student learning, with a mean effect size of .65.

Inquiry based lessons usually start with a central question from which students derive sub questions to help them answer the central question. Students find the answers to these questions in information sources, like the library or the internet, through observations or by conducting experiments (Lonka et al., 2000). There are several inquiry models available in the research literature which describe different inquiry frameworks or cycles (Bell et al., 2010). Pedaste et al. (2015) have studied 32 different inquiry frameworks and cycles and have combined them to create their own inquiry cycle, which consists of five inquiry phases: *Orientation, Conceptualization, Investigation, Conclusion*, and *Discussion*. Their inquiry cycle, as is displayed in figure 1, was used to design the lessons in this study. The five inquiry phases are described in the next paragraph.

In the *Orientation* phase, students get interested in a specific topic (Pedaste et al., 2015). Students’ curiosity can be awakened by using children’s books (Saçkes, Trundle, & Flevares, 2009), through immersive experiences (McMahon-Whitlock & Brugar, 2017) or by asking questions about everyday experiences (Howitt et al., 2011). Curious students are motivated to inquire and explore (Jirout & Zimmerman, 2015). The *Orientation* phase leads to the development of a problem statement (Pedaste et al., 2015). In the *Conceptualization* phase, the students grasp the research problem and ask questions about it. This phase leads to either open research questions or testable hypotheses (Pedaste et al., 2015). In the *Investigation* phase, students carry out an investigation to find the answers to their questions. This can be done by observing, exploring, or conducting an experiment. At the end of this phase, students interpret the data they have gathered and return to their research questions or hypotheses (Pedaste et al., 2015). Finally, students get to the *Conclusion* phase, in which they must draw a conclusion based on the findings of the data-analysis (Pedaste et al., 2015). The fifth phase, *Discussion*, is a continuous step in the inquiry process and consists of communication and reflection, which are meta-cognitive processes that are important for the inquiry process (Pedaste et al., 2015). Students need to discuss and elaborate on the inquiry process together, to come to an understanding of their findings. Perrin (2004) argues that communicating the results of the inquiry process is an important skill in IBL and that teachers should encourage students to use appropriate scientific vocabulary (e.g. hypothesis, experiment, observe) to develop this skill. Reflection helps students to understand the inquiry process and content (Quintana et al., 2014; White & Frederiksen, 1998). By reflecting on the inquiry process with their peers, students can learn from each other’s ideas and experience that different perspectives exist.

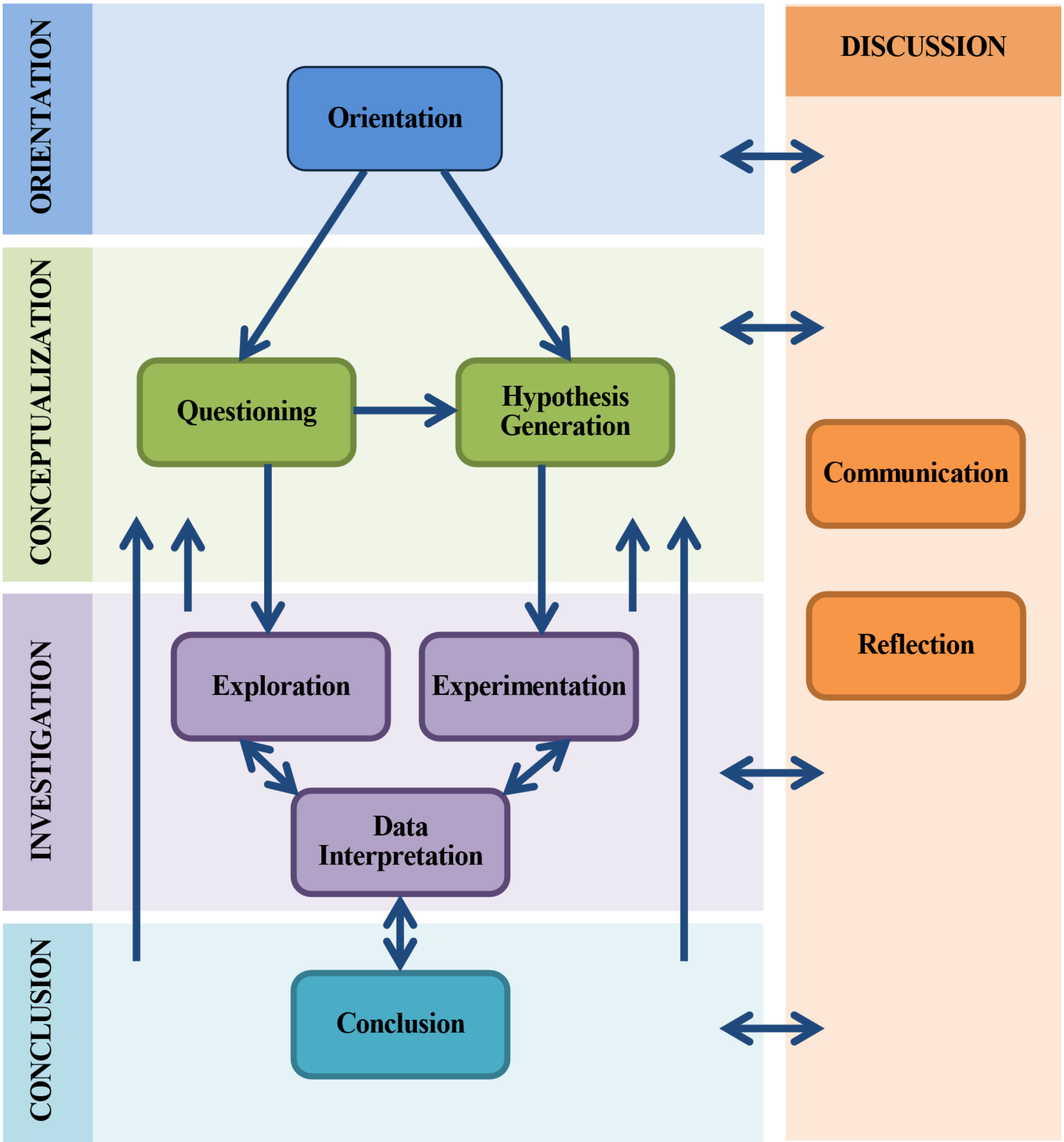

Figure 1. Inquiry-based learning framework: general phases, sub-phases, and their relations (Pedaste et al., 2015, p. 56).

1.2 Scaffolding Inquiry Based Learning with Young Children

Marian and Jackson (2016) recommend using inquiry as a teaching strategy at a very young age, when children are most curious about the world around them, to build a foundation for developing science skills as they grow older. In the last couple of years, several studies have been conducted with younger students, showing that young children are already able to successfully participate in IBL. Kim et al.

(2012) conducted a study with 3.300 students from kindergarten up to third grade to examine the effect of an inquiry-based science curriculum on student learning. The intervention groups showed more progression in science learning than the control groups. Samarapungavan et al. (2008) conducted a study with kindergarten students who engaged in inquiry-based lessons about the life cycle of the monarch butterfly. The intervention group outperformed the control group on the understanding of scientific inquiry processes, which was measured with the Science Learning Assessment (SLA), an assessment tool developed by the authors. Wolf and Laferriere (2009) describe the inquiry process of first and second grade students who participated in an inquiry unit about hermit crabs. The students in this case study were able to ask scientific questions and come up with experiments to answer their questions. In another study, Varma (2014) investigated the development of conceptual understanding in first and third grade students who learned about the thermodynamics system. The intervention group outperformed the control group on the post-tests and demonstrated that they were better at making connections between the concepts learned in the project. The author concludes that IBL helps young students to develop understanding of scientific phenomena.

What are the conditions for successfully conducting IBL with young children? Young children need to be guided through their learning process, and Varma (2014) stresses the importance of teacher guidance when conducting IBL with elementary school students. Different strategies to guide young students in IBL can be found in the research literature. Samarapungavan et al. (2008) suggest that teachers guide students in the inquiry process through class discussions and helping students to share what they have learned, for instance by using portfolios. Wolf and Laferierre (2009) recommend using a chart to help students organize their knowledge about the topic, and Saçkes et al. (2009) suggest the use of children’s books to introduce science concepts.

In addition to student guidance through learning materials, such as described above, scaffolding the learning process also is an effective strategy to guide young students. Hmelo-Silver et al. (2007) argue that teachers need to scaffold student learning to reduce cognitive load. Scaffolding helps students to understand new information, complete difficult tasks and eventually to perform inquiry independently, and is especially important when conducting IBL with young students (Kim et al., 2012). Varma (2014) proposes using laboratory notebooks to scaffold the inquiry process, and Cuevas et al. (2005) discuss a gradual decrease of teacher guidance and increase of student initiative as an effective scaffolding strategy. Samarapungavan et al. (2008) suggest scaffolding by asking questions and providing hints and clarifications when needed. Another strategy to provide scaffolding, is to have students collaborate with their peers (Ge & Land, 2003). Collaboration between students is important for the success of IBL (Hmelo-Silver et al., 2007) and a key variable in this study, which will be discussed in the next section.

1.3 Collaborative Learning in IBL

Collaborative learning is defined as students working together to solve a problem or complete an assignment (Saab et al., 2007). Dillenbourg (1999) describes collaborative learning as a situation in which the interaction between students precipitates the learning process. Research shows that students who collaborate with peers achieve higher learning gains than students who learn individually (Manlove, Lazonder, & De Jong, 2009). Teasley (1997) argues that students are enforced to elaborate their own reasoning when collaborating with a peer, which is essential in IBL.

The positive effect of collaboration on student learning has been demonstrated in many studies in the last decades. Lazonder (2005) examined how effective either pairs of students or individual students conducted web searches and found that pairs outperformed individual students. Pairs also outperformed individual students in a study on online inquiry learning by Manlove et al. (2009).

Collaborative learning is a key factor for the success of IBL (Hmelo-Silver et al., 2007). As aforementioned, collaboration with peers scaffolds the learning process, because students learn from each other and can elaborate on each other's ideas. Many researchers have studied collaborative learning in the field of IBL. Saab et al. (2007) argue that collaboration can help students to generate more variation of hypotheses, which is an important step in the IBL process. Osborne (2010) underlines the importance of being critical and being able to reason and argue in science and claims that students can only learn this by collaborating with their peers. Bell (2004) shares this opinion and discusses the importance of collaborative debate in science education, so students get to understand that different, often even opposing, theories exist in science and that it is important to be critical. Through collaboration with their peers, students experience that their own point of view is not the only angle to approach a problem and that together they can achieve more than alone. Weinberger and Fischer (2006) reason that students construct new knowledge through argumentative discourse. Collaborative learning not only leads to better learning gains but can also lead to increased motivation. Research on collaborative learning in mobile learning trails by So, Tan, and Tay (2012) showed both positive learning results and a positive learning experience from the learners' perspective.

However, collaboration between students is not always successful. Barron (2003) studied the collaboration process of 6th grade students collaborating on solving math problems from a storyline called 'Journey to Cedar Creek' to gain insight into why some collaborate groups succeed, and other groups fail. Her findings indicated that successful groups discussed or accepted each other's correct proposals more than unsuccessful groups, in which correct proposals were often ignored or rejected. In analysing why groups differed in their reactions to correct proposals, Barron noticed that successful groups created a joint problem-solving space in which students shared their ideas and listened to each other. Collaboration was less successful when one or two members from a group were unwilling to collaborate with peers or when peers argued about turn-taking. Barron (2003) stresses the importance of students reacting to each other's contributions to collaborate successfully and to benefit from the collective knowledge of the collaborative group. This leads to the conclusion that students not only need guidance in their learning process, but in the collaboration process as well.

1.4 Structured and Unstructured Collaborative Learning

In a collaborative learning situation, students work together in small groups to discuss and solve problems (Tomcho & Foels, 2012), and this teaching strategy is regularly used in elementary schools (Saleh, Lazonder, & De Jong, 2007). It is important that students verbalize their reasoning when they collaborate with peers, so they can learn from each other and together can solve the problem (Saab et al., 2007). These kinds of interactions between students do not occur spontaneously though (Dillenbourg, 1999). Students could be guided too much by their own prior knowledge, disregarding new facts or knowledge. Or students fail to listen and respond critically to their peers' contributions, in order to quickly reach consensus. Some students might not even participate in the group process at all, leading to social loafing (Veenman et al., 2000). How to avoid this from happening?

As aforementioned, students need guidance to collaborate successfully and collaboration between students only has a positive effect on student learning when individual accountability and positive interdependence are guaranteed. Teachers need to structure the collaboration process to accomplish this. Collaboration can be structured by giving students specific roles and/or imposing interaction rules, such as having all group members share their opinion before the group may continue (Dillenbourg, 1999). The use of collaboration scripts is an effective strategy to structure collaboration (Kollar et al., 2007). Scripts are detailed instructions on how the students should collaborate, such as how groups should be formed, how group members should interact, and which steps the students should take in their collaboration process (Dillenbourg, 2002). Weinberger et al. (2005) distinguish between epistemic and social scripts. Epistemic scripts structure the learning task, in order to guide students in their learning process. For example, by using tables to structure the lesson content. Epistemic scripts, as opposed to social scripts, can be used in individual learning situations as well. Social scripts structure the collaboration process itself, by structuring the interaction patterns between students. The use of social scripts can lead to more conflict-oriented discussions between students, which teaches students to look at different viewpoints and to elaborate on their own and their peers' perspectives. However, the authors warn against negative effects of scripts. Negative effects can occur when scripts are too structured, preventing students from freely sharing their thoughts with their peers. Dillenbourg (2002) refers to this effect as 'over-scripting' and explains that it could influence the richness of group interactions as the natural collaboration processes between students are affected. He defines collaboration scripts as instructions on how students should interact and collaborate and warns educators that scripts should be kept simple and with an appropriate level of coercion, otherwise they will lead to decreased student motivation. Rummel and Spada (2005) comply and claim that, although scripts can be effective in structuring the collaboration process, they can also lead to motivation problems when the group's discourse is regulated too rigidly.

Nonetheless, structuring the collaboration process by using scripts leads to higher learning gains than collaboration without a script, considering students use the script correctly (Weinberger et al., 2005). When the collaboration process between students is not structured, students decide for themselves how they work together (Saleh et al., 2007). There are no interaction rules and there is no turn-taking mechanism in place. Individual accountability and positive interdependence are not guaranteed in unstructured collaboration, making it possible for social loafing to occur. Previous research on structured and unstructured collaboration implies a positive effect of structured collaboration on students' discourse and learning gains.

Saleh et al. (2007) conducted a study on structured and unstructured collaboration with 4th grade students. In the experimental condition, collaboration was structured by giving the students index cards containing rules for helping behaviour and by using a turn-taking mechanism, ensuring everyone's participation. Collaboration between students in the control groups was not structured; the students worked together without any constraints. The study showed that students in the structured condition interacted more actively and gained higher scores on the post-tests than the students in the unstructured condition.

Aslan (2015) researched the difference between unstructured and structured collaboration of 5th grade students. Collaboration in the experimental condition was structured by assigning roles to the students. Her study found that student interactions are more effective in structured collaborative learning, leading to better learning gains and a more positive attitude towards collaborative learning.

In this study, the focus is on the use of structured and unstructured collaboration in IBL with young elementary students. Based on findings in the research literature, the use of structured collaboration in IBL is expected to lead to a more effective group discourse, which in turn should lead to better learning gains. However, findings found in the research literature are based on studies with older students. Structured and unstructured collaboration in IBL with young elementary students is an under-researched area. Do the same effects occur when structuring collaboration with young students?

1.5 Processes and Outcomes of IBL

This section discusses the effects of collaborative IBL. Not only is it interesting to look at the students' learning gains, it is also important to study the effects on the inquiry and collaboration processes. First, the effects on learning gains and inquiry processes are described. Second, the effects on collaboration processes.

1.5.1 Declarative knowledge and procedural knowledge.

As structuring the collaboration process is expected to lead to better learning gains, in IBL this should be visible in students' recall in knowledge on the lesson content (declarative knowledge) as well as on their knowledge on scientific inquiry processes (procedural knowledge). Schraw, Crippen, and Hartley (2006) reason that collaborating with peers helps students to increase their declarative and procedural knowledge, because students learn from each other and are encouraged to discuss and reflect on scientific concepts. Student interactions often also increase students' engagement and motivation, leading to better learning gains.

Declarative knowledge in science education refers to recalling facts, definitions and concepts (Abu-Zaid & Khan, 2013). Students need declarative knowledge to learn and understand new science concepts and to be able to analyze science problems (Pals, Tolboom, Suhre, & Van Geert, 2018). A study on the effect of collaborative (game-based) science learning by Sung and Hwang (2013) demonstrated the positive effect of collaborative learning on elementary students' declarative knowledge on identifying plants. Students in the intervention group were engaged in collaborative learning and outperformed their peers who learned individually.

Procedural knowledge refers to knowledge related to procedures within a domain (De Jong & Ferguson-Hessler, 1996). In IBL, procedural knowledge refers to scientific inquiry processes, such as formulating hypotheses and conducting experiments (Van Uum, Verhoeff, & Peeters, 2016). Riley and Anderson (2006) compared the effect on procedural knowledge acquisition between two groups of public health students in a distance learning program. The intervention group worked collaboratively on tasks and the control group worked individually. The intervention group outperformed the control group on procedural knowledge regarding inquiring and presenting knowledge in the public health domain. A study by Rojas-Drummond, Hernández, Vélez, and Villagrán (1998) on procedural knowledge acquisition for processing texts with 9-year-old students, produced similar findings. The intervention group (collaborative teams) outperformed the control group (individual learning). The assessment tool developed by Samarapungavan, Mantzicopoulos, Patrick, and French (2009), the *Science Learning Assessment* (SLA), measures the procedural knowledge in scientific inquiry processes in young students. This tool was used in this study as well.

1.5.2 Group discourse in collaborative IBL.

The effects of structuring the collaboration process on students' declarative and procedural knowledge are important. However, it is crucial to also determine the effect of structuring the collaboration process on how effectively students work together, as this gives deeper insight into the collaboration process itself and on how to improve this process. The effectiveness of the collaboration process can be determined by looking at the quality of the group discourse. When analysing the group discourse it is important to look at both the epistemic and social dimension, because this not only provides information on how students work on their tasks, but also on how students react to their peers' contributions.

The epistemic dimension refers to how students are engaged on the learning task (Weinberger & Fischer, 2006). Is student discourse on-task or off-task? Discourse is on-task when students attempt to solve the learning task by verbalizing their ideas and structuring their knowledge. In on-task discourse, a distinction can be made between different epistemic activities, such as surfacing a new idea (contribution), elaborating on an idea (elaboration) or sharing an opinion (positioning). A detailed description of the coding scheme for the epistemic dimension, which is used in this study, is outlined in the method section of this paper.

The social dimension refers to how students build on each other's reasoning, which Weinberger et al. (2005) define as transactivity. When peers successfully build on each other's reasoning, learning is likely to occur (Popov, van Leeuwen, & Buis, 2017). In the social dimension a distinction can be made between different social modes, depending on how students reach consensus (Weinberger & Fischer, 2006). For example, students can accept each other's contributions without questioning them (quick-consensus building), take over or integrate each other's perspectives (integration-oriented consensus building), or critically listen to each other's contributions and adjust them or turn them down (conflict-oriented consensus building). The quality of group discourse is measured by the level of transactivity. According to Weinberger and Fischer (2006) the different social modes represent different levels of transactivity. A high level of transactivity is related to the number of conflict-oriented discussions between peers, as conflict is the source of cognitive growth (Bell, Grossen, & Perret-Clermont, 1985). Popov et al. (2017) studied dyads of first-year university students learning about biodiversity in a computer-supported collaborative learning setting. Findings of this study indicated that a high level of transactivity leads to better learning outcomes than a low level of transactivity. De Weerd, Tan, and Stoyanov (2017) argue that verification, clarification and positioning statements in the epistemic dimension are of importance in order to reach the higher levels of transactivity in the social dimension. A higher level of transactivity is reached when students critically listen to and build on each other's contributions. Hence, asking for verification, clarifying thoughts and positioning perspectives are necessary to reach this higher level of transactivity, as these statements force students to explain and re-consider their contributions. A detailed description of the coding scheme for the social dimension, which is used in this study, is also outlined in the method section of this paper.

1.6 Research Questions and Hypotheses

The overarching question for this empirical study is: "What are the effects of structured and unstructured collaboration on collaborative inquiry-based learning in early elementary school students?" Based on the literature review and past empirical studies on structured collaboration, it was hypothesized that structured collaboration leads to a better recall of declarative knowledge, a better procedural knowledge of scientific inquiry processes and a higher quality of group discourse than unstructured collaboration. The main research question thus leads to three hypotheses:

RQ1: What is the effect of structured and unstructured collaboration on the declarative knowledge of early elementary students in collaborative inquiry-based learning?

H1 Structured collaboration in collaborative inquiry-based learning with early elementary students leads to a better recall of declarative knowledge than unstructured collaboration.

RQ2: What is the effect of structured and unstructured collaboration on the procedural knowledge in scientific inquiry processes of early elementary students in collaborative inquiry-based learning?

H2 Structured collaboration in collaborative inquiry-based learning with early elementary students leads to a better procedural knowledge in scientific inquiry processes than unstructured collaboration.

RQ3: What is the effect of structured and unstructured collaboration on the quality of discourse amongst early elementary students in collaborative inquiry-based learning?

H3 Structured collaboration in collaborative inquiry-based learning with early elementary students leads to a higher quality of group discourse than unstructured collaboration.

A conceptual model of this study is displayed in figure 2. The model shows the research methods which are conducted to study the effects of structured and unstructured collaboration on the different dependent variables in this study. As is displayed in this figure, both quantitative and qualitative research are conducted to study these effects.

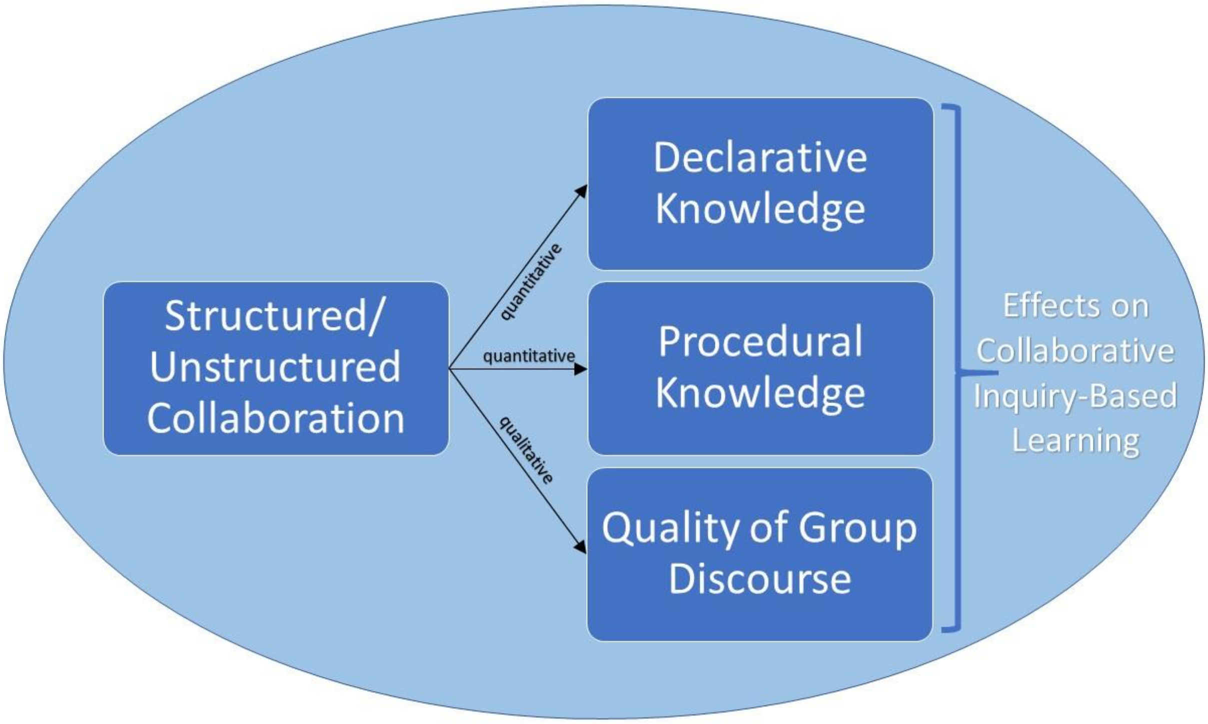

Figure 2. Research model displaying the variables and research methods in this study

2. Method

2.1 Research Design

A mixed method study with early elementary students was conducted to test the hypotheses. The independent variables in this study were structured and unstructured collaboration. The participants participated in two inquiry-based lessons in which the intervention group used structured collaboration and the control group unstructured collaboration. The effects on collaborative inquiry-based learning were measured using both quantitative and qualitative data.

Quantitative data were collected to measure the effect on learning outcomes (declarative knowledge) and the effect on the inquiry process (procedural knowledge). Qualitative data (transcribed recordings of the groups' discourse in this study) were collected to measure the effect on the collaboration process (quality of group discourse).

Hypothesis 1, the effect on recalling declarative knowledge, was measured using a pre- and post-test on the lesson content. Hypothesis 2, the effect on procedural knowledge of scientific inquiry processes, was measured with the *Science Learning Assessment* (Samarapungavan et al., 2009). Hypothesis 3, the effect on the quality of interaction, was measured by collecting qualitative data as this gives deeper insight into the collaboration process than quantitative data.

The inquiry-based lessons were developed by the researcher, according to the inquiry cycle of Pedaste et al. (2015). The lesson topic was gravity and air resistance. As scaffolding and teacher guidance are important in IBL with young students (Hmelo-Silver, Duncan, & Chinn, 2007), different strategies were used to scaffold the learning process and to guide the students. Having students collaborate with their peers was a key strategy in the lesson plan. To guide the students in this process, lesson parts in which the students collaboratively learned through self-discovery (e.g. by conducting experiments), were alternated with teacher guided class discussions. Furthermore, the students received a science notebook to scaffold learning, the teacher modelled important parts of the inquiry process, (e.g. stating a hypothesis, conducting an experiment and recording results in the science notebook) and students were given sentence starters (e.g. My hypothesis is...) to help them use appropriate scientific vocabulary when expressing their thoughts and opinions. In the intervention group, the collaboration process itself was scaffolded as well, using a social script (turn-taking cards and interaction rules).

2.2 Participants

The study took place at the European School Mol in Belgium. The school consists of a nursery, a primary, and a secondary school. Students at this school represent many different nationalities and the school has four linguistic sections: a German-, English-, French- and Dutch-speaking section. Two primary classes from the Dutch- and English-speaking section (43 students in total) participated in this study. The parents were asked to give a written consent. For one student consent was not given by the parents and one student was ill during the time the research took place. One participant was absent on the day the post-test and SLA were administered. This participant did complete the pre-test and the lessons. Because the pre- and post-test could not be compared, this participant was excluded from the quantitative analysis.

The participants in this study were students from the second grade of the Dutch- and English-speaking section of the primary school (n=40). There were 19 participants from the English-speaking section and 21 participants from the Dutch-speaking section. The group consisted of 16 boys and 24 girls and the average age of the participants was 7.45 years old (SD = .50). The age range was 7 to 8 years old.

Stratified sampling was used to divide the students into groups. Stratification divided the participants into Dutch- and English-speaking groups, because the students needed to participate in the lessons in their section’s language of instruction. Students from both sections were then randomly assigned to the intervention or control group. This means that the lessons were taught in four groups as is displayed in Table 1.

Table 1

Participants in the Experimental Design with Two Conditions

Condition	N	Language of Instruction	%Male	%Female	Mean Age
IG total	20		35	65	7.45
IG 1	9	English	33	67	7.22
IG 2	11	Dutch	36	64	7.64
CG total	20		45	55	7.45
CG 1	10	English	50	50	7.60
CG 2	10	Dutch	40	60	7.30

Note. IG = Intervention Group (Structured Collaboration), CG = Control Group (Unstructured Collaboration)

2.3 Materials

The participants participated in two inquiry-based lessons in which they used toys and paper toy helicopters to learn about gravity and air resistance, while going through a full inquiry cycle. The lessons were designed by the researcher and all lessons were taught by one teacher from the school, who teaches in both the Dutch- and English-speaking section. The researcher provided a detailed lesson plan and all lesson materials in both languages.

Students in all four groups followed the exact same lesson procedure. The lesson content was the same, and in all groups the students had to collaborate. In the intervention group, the collaboration process was structured, using a turn-taking mechanism (turn taking cards with sentence starters, which forced all students to contribute). The turn-taking cards are displayed in figure 3. Students were also given interaction rules (everyone gets a turn, turns are taken clockwise), which ensured individual accountability and positive interdependence. In the control group, the collaboration process was not structured. Students in the control group did receive the sentence starters to help them discuss their hypotheses or complete an assignment together, but without specific instructions on turn-taking and without the strict interaction rules of the intervention group.

The pre- and post-test on the lesson topic (appendix 1), was a pen and paper test with 16 multiple choice questions which measures recalling declarative knowledge about the lesson topic. The test was designed after completing the design of the inquiry-based lessons and the data obtained from this test resulted in a quantitative pre- and post-test score. The participants were also asked to indicate their age, gender, and linguistic section to enable controlling for these variables. After administering the tests, a reliability analysis was conducted to ensure the tests' internal consistency.

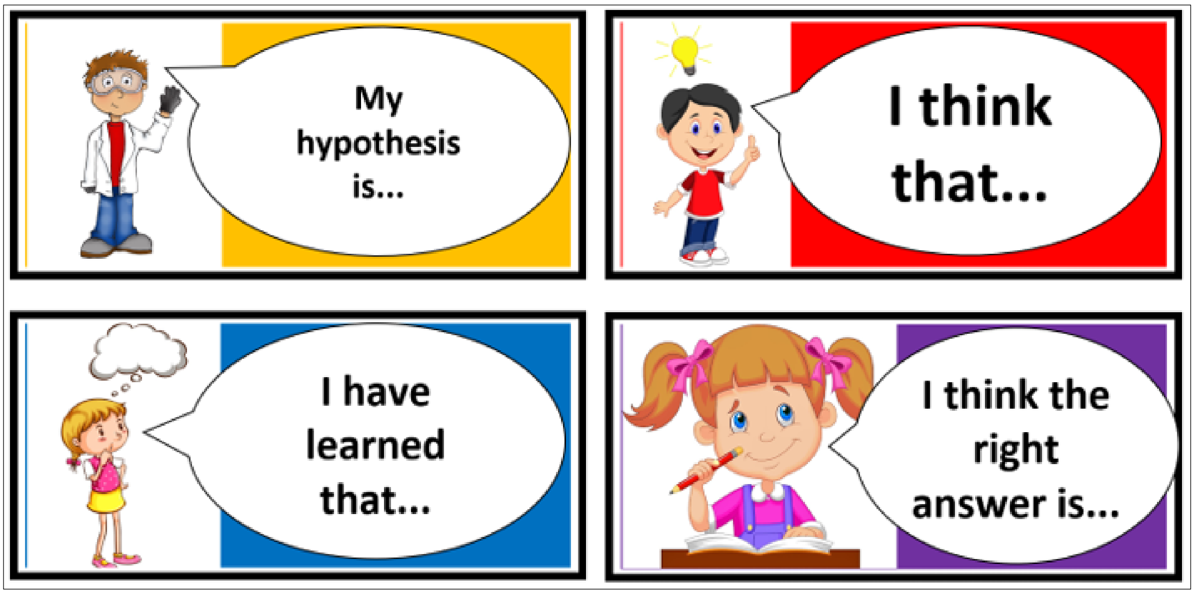

Figure 3. Turn taking cards with sentence starters

The Science Learning Assessment (SLA), which measures procedural knowledge of scientific inquiry processes, was obtained from the authors (Samarapungavan et al., 2009). The questions in the SLA were adapted to make them age appropriate for the participants in this study, because the original SLA was developed for Kindergarten students. The SLA consists of 24 items: the first nine items assess children's understanding of scientific inquiry processes and the next 15 items assess their understanding of life science concepts (e.g. questions about animals and plants). For this study only the items which measure the understanding of scientific inquiry processes were relevant, since these questions assess the procedural knowledge of scientific inquiry processes. Because nine items were not sufficient to give a reliable test score, more items (similar to those in the original SLA) were added to create a test with 20 items. The items in the original SLA are questions with pictures and the test is administered individually. The students are asked to answer the questions by pointing to a picture. In the adapted SLA (appendix 2), pictures were used as well, but as the students in this study were old enough to read, the SLA was administered as a pen and paper test and was added to the post test. A reliability analysis was performed after administering the test to measure the internal consistency of the items in the adapted SLA.

The collaboration process of the students in both intervention groups and both control groups was recorded (voice and video recordings) for qualitative analysis. In each lesson, three voice- and three video recorders were used, because the students in each session were divided into three collaborative groups of three to four students. The recordings were transcribed, and the transcribed recordings were scored using validated rubrics, which are described in paragraph 2.5.

2.4 Procedure

Data collection took place in June 2018 at the European School Mol. For this study, students from two second grade classes from the Dutch- and English-speaking section engaged in inquiry-based lessons. All lessons were taught by a teacher from the European School Mol, who teaches in both linguistic sections. The school management gave their consent for the study and the parents were asked to give a written consent for their child to participate in the study. Approval for this study by the Research Ethics Committee (cETO) was obtained before data collection took place, and insurance was arranged for the participants, because the study took place in Belgium.

One day before the inquiry-based lessons took place, the pre-test was administered to all participants in consultation with their teachers. The researcher administered the pre-test in the respective classrooms of the second-grade students. Administering the pre-test took approximately 15 minutes.

The lessons were then taught in the next days in four groups: a Dutch- and an English-speaking intervention group and a Dutch- and an English-speaking control group. Every group participated in two inquiry-based science lessons (45 minutes per lesson) about gravity and air resistance. All lessons took place at the same time (11.00 am – 11.45 am) on two consecutive days. The lessons were designed by the researcher and all lesson material was provided in both Dutch and English. The teacher received instructions on how to teach the lessons and specifically on how to structure the collaboration process in the intervention group. The researcher attended all eight lessons and recorded the collaboration process of all students in each group to collect data for qualitative analysis.

One day after completing the lessons, the post-test and the SLA were administered to the participants in consultation with their teachers. The researcher administered the post-test and SLA. Administering the post-test and SLA took approximately 30 minutes. The research procedure is displayed below in figure 4.

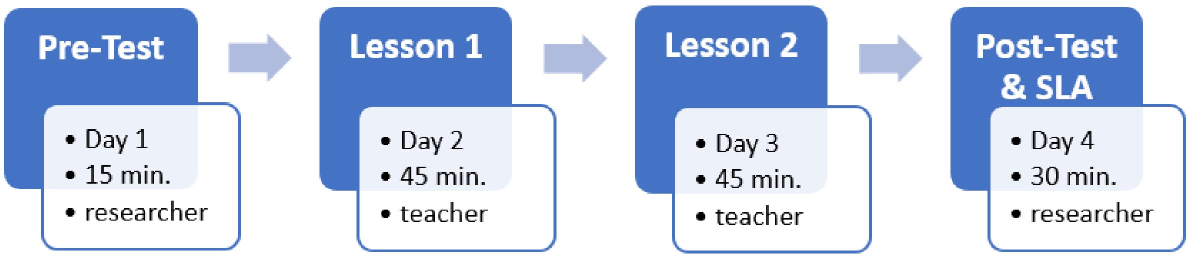

Figure 4. Research procedure for all four experimental groups

2.5 Date source and data-analysis

Both quantitative and qualitative data were collected. The scores on the pre- and post-tests and the SLA provided quantitative data, and the transcribed recordings provided the qualitative data.

The pre- and post-test scores were compared in a paired sample t-test to find out if the inquiry-based lessons had an impact on the participants' declarative knowledge about the lesson topic. Hypothesis 1, the effect of structured or unstructured collaboration on recalling declarative knowledge, was measured with a one-way ANCOVA to compare the difference between the pre- and post-test scores for the intervention and control group, controlling for age, gender and linguistic section. The significance level was set at $p < .05$.

Hypothesis 2, the effect of structured or unstructured collaboration on procedural knowledge of scientific inquiry processes, was measured with a one-way ANCOVA to compare the SLA scores for the intervention and control group, controlling for age, gender and linguistic section. The significance level was set at $p < .05$.

Hypothesis 3, the effect of structured or unstructured collaboration on the quality of group discourse, was measured using the transcribed recordings of the collaboration process in the different groups. The transcribed recordings were scored on the epistemic and the social dimension using validated rubrics. A second rater was asked to code part of the recordings to assess the interrater reliability and the data were checked for outliers before comparing the intervention and control group.

First the transcripts were divided into utterances, collections of words with a single communicative function. The utterances were then categorized according to their communicative functions. In the epistemic dimension there was a total of 599 units of analysis for the intervention group and 629 for the control group. Table 2 displays the types of utterances, descriptions, and examples of each utterance for the epistemic dimension.

Table 2

Overview of coding categories and sample statements for the epistemic dimension (adapted from Saleh et al., 2007)

Code	Description	Example
Contribution	Surface an idea/ concept in which a new topic of conversation not discussed before is introduced.	My hypothesis is the little ball, because it is heavier.
Verification	Request information about the intended meaning of a contribution or elaboration.	Why the Duplo?
Clarification	React to a verification and/or seek further explanation to check for understanding.	I tell you. Because it is made out of harder material.
Elaboration	Expand an idea/ a concept by adding more information.	Both of the same width, they will fall at the same time.
Positioning	Summarize one's viewpoint and take a position by agreeing, disagreeing, accepting or rejecting.	No, it is the ball.

Regulation	Utterances related to monitoring the problem-solving process and regulating the collaboration process.	And now we answer the question.
Off-task	Utterances not related to the task.	You can't tie shoe laces?

Utterances were then grouped into episodes of consecutive, topic-related utterances, which were coded for the social dimension, which describes to what extent learners build on the contributions of their peers. There was a total of 208 units of analysis for the intervention group and 219 for the control group. Table 3 displays the coding categories, descriptions, and sample statements for the social dimension.

Table 3

Overview of coding categories and sample statements for the social dimension (adapted from Weinberger & Fischer, 2006)

Code	Description	Example
Externalization	Contribute to discourse without any explicit or implicit references to previous contribution.	I think that the helicopter with folded blades will hit the ground first.
Elicitation	Request information/ feedback from learning peers.	Which one is going to land first?
Quick consensus building	Accept a peer contribution without any modification.	A: Both fall at the same time. B: My hypothesis is that they both will fall at the same time, so we all think that.
Integration-oriented consensus building	Take over the perspective of their learning peers and/ or integrate different perspectives.	A: The frisbee of course...it's flat. B: It's flat, so it will go like this (shows whirling movement with hands). A: So, the... C: The stuffed animal B: So, it's the stuffed animal D: The stuffed animal C: Yes, except when you're very bad at throwing frisbee's. Then the frisbee will come down fast.
Conflict-oriented consensus building	Reject and/or repair contributions of their learning peers with further replacement, modification and/or supplementation.	A: Both of them at the same time. Both of them are the same weight. B: It's not. Look, it's not the same weight. No, remember what she said? One heavy, one light. And the ball, remember the ball and the stuffed animal? They were not the

		same weight. But they still...
Not-relevant	Utterances which are not relevant to the task.	A: Do you have earrings? B: Yes A: Not anymore? B: Yes, but I'm not wearing them now.

The quality of the group discourse between both conditions was compared through the level of transactivity. The different social modes represent different levels of transactivity with the lowest level of transactivity being externalization and the highest level of transactivity being conflict-oriented consensus building (Weinberger & Fischer, 2006). Chi-square tests of independence were performed to examine the relation between both conditions and the epistemic- and social dimensions. The significance level was set at $p < .05$. Compare column proportions tests were performed to investigate the relationship between the conditions and the specific processes in the epistemic- and social dimension.

3. Results

3.1 Reliability Analyses

The reliability analysis of the data obtained from the pre-test, which assessed children's declarative knowledge before participating in the inquiry-based lessons, indicated adequate internal consistency of the test items. Cronbach's $\alpha = .76$, 16 items. The reliability analysis of the data obtained from the post-test, which assessed children's declarative knowledge after participating in the inquiry-based lessons, also indicated adequate internal consistency of the test items. Cronbach's $\alpha = .77$, 16 items.

The reliability analysis of the data obtained from the adapted SLA indicated poor internal consistency of the test items. Cronbach's $\alpha = .58$, 17 items (questions 1,2 and 14 had zero variance and were removed from the scale). After also removing questions 3, 8, 9, 17 and 18 (Item-Total Correlation < 0.2) the reliability analysis indicated adequate internal consistency of the remaining test items. Cronbach's $\alpha = .70$, 12 items.

To assess the interrater reliability of the coding process, a second rater was asked to code the recordings of two out of the twelve groups of students (= 16.7%). The interrater agreement on both the epistemic dimension (Cohen's Kappa $\kappa = .73$) and the social dimension (Cohen's Kappa $\kappa = .90$) was sufficient.

Before comparing the qualitative data between the intervention and control group, the data were checked for outliers. The analyses showed no outliers in total number of utterances per group for the epistemic and social dimensions, but looking at specific utterances, 'positioning' in the epistemic dimension stood out (one of the collaborative groups generated many utterances which were coded positioning). There were also some minor outliers for ‘elaborations’ and ‘off-task’ in the epistemic dimension and for ‘elicitations’ and ‘not-relevant’ in the social dimension. The dataset was checked for errors, but no errors were found. The data represent the number of statements the students made, and it was therefore decided not to eliminate data from the dataset.

3.2 Quantitative Analysis

The effect of structured or unstructured collaboration on recalling declarative knowledge (hypothesis 1) and on procedural knowledge of scientific inquiry processes (hypothesis 2) was measured with the quantitative data obtained from the pre- and post-test and the SLA. Table 4 displays the mean scores and standard deviations of the scores on the pre- and post-test and the SLA for both experimental conditions.

Table 4

Descriptive statistics of the quantitative test scores

Test scores	Mean (*Standard Deviation*)		
	Intervention Group (*n* = 20)	Control Group (*n* = 20)	Total (*n* = 40)
Pre-Test	2.25 (*2.02*)	3.85 (*3.20*)	3.05 (*2.76*)
Post-Test	9.70 (*3.48*)	9.85 (*3.59*)	9.78 (*3.49*)
Difference Pre-Test and Post-Test	7.45 (*3.41*)	6.00 (*3.42*)	6.73 (*3.45*)
SLA	10.00 (*2.29*)	9.50 (*2.06*)	9.75 (*2.17*)

The pre- and post-test scores were compared to find out if the inquiry-based lessons had an impact on the participants’ declarative knowledge about the lesson topic. A paired T-test indicated a significant difference between the pre-test (M = 3.05, SD = 2.76) and the post-test (M = 9.78, SD = 3.49), $t(39) = -12.33$, $p < .001$.

A One-way ANCOVA was conducted to determine if there was a significant difference between the intervention and control group on the difference between the pre- and post-test score, controlling for age, gender and linguistic section. There was no significant effect of the condition on the difference between pre- and post-test score after controlling for age, gender and linguistic section, $F(1,35) = 1.42$, $p = .24$ There was also no significant effect of the covariates ‘age’ and ‘gender’ on the difference between pre- and post-test, but there was a significant effect of the covariate ‘linguistic section’ on the difference between pre- and post-test, $F(1,35) = 4.44$, $p = .04$. The mean score on difference between post-test and pre-test for students from the English class (M = 5.53, SD = 2.48) was lower than the mean score for students from the Dutch class (M = 7.81, SD = 3.88). There was no significant difference between scores on the Post Test of the English class (M = 9.84, SD = 3.30) and the Dutch class (M = 9.71, SD = 3.73), but the students from the English class scored higher on the Pre-Test (M = 4.32, SD = 3.06) than the students from the Dutch class (M = 1.90, SD = 1.89).

A One-way ANCOVA was conducted to determine if there was a significant difference between the intervention and control group on the SLA score, controlling for age, gender and linguistic section. There was no significant effect of the condition on the SLA score after controlling for age, gender and linguistic section, $F(1,35) = .53$, $p = .24$. There was also no significant effect of the covariates ‘gender’ and ‘linguistic section’ on the SLA score, but there was a significant effect of the covariate ‘age’ on the SLA score, $F(1,35) = 4.54$, $p = .04$. The mean score on the SLA for 7-year-old students (M = 9.09, SD = 2.35) was lower than the mean score for 8-year-old students (M = 10.56, SD = 1.65).

3.3 Qualitative Analysis

The effect of structured or unstructured collaboration on the quality of group discourse (hypothesis 3), was measured by collecting qualitative data (transcribed recordings of the groups’ discourse in this study). The qualitative data were coded on both the epistemic and social dimension. Figure 5 displays occurrences of statements for the intervention group and the control group in the epistemic dimension. The overall findings showed no significant differences in occurrences of statements between both conditions.

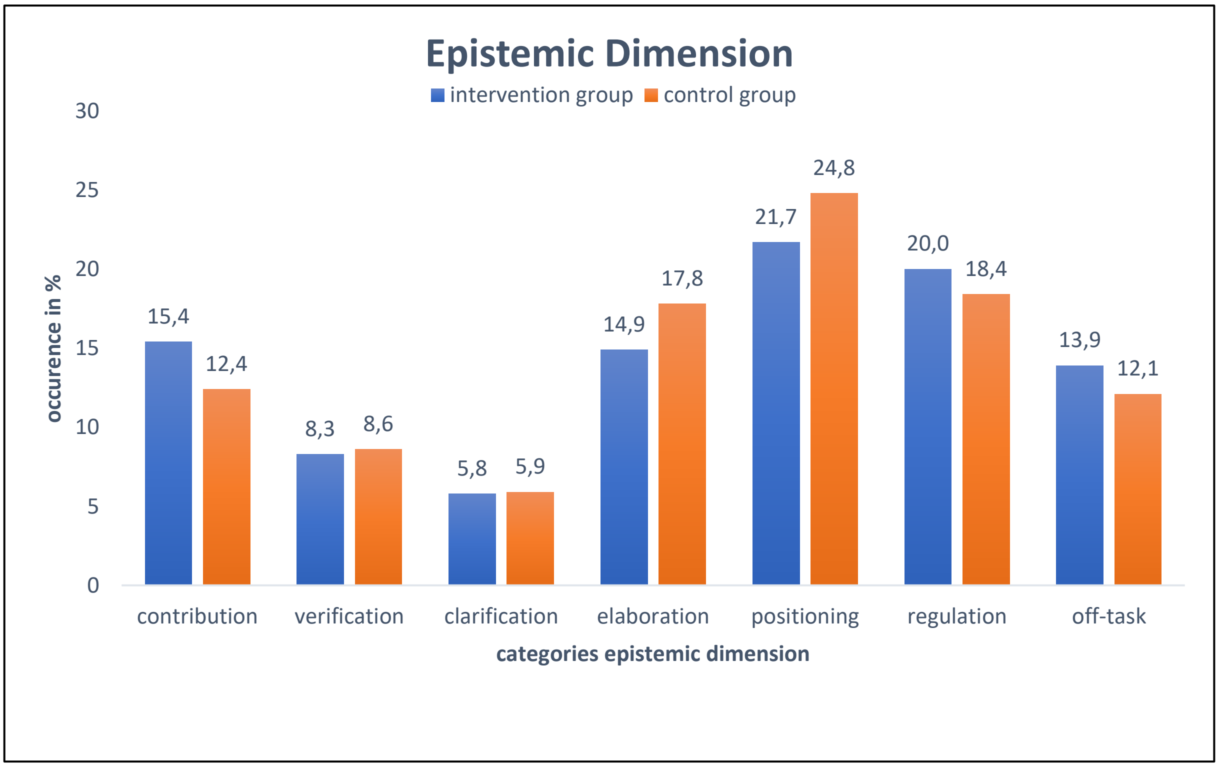

Figure 5. Occurrence (N%) of the seven categories in the epistemic dimension.

A Chi-square test of independence was performed to examine the relation between both conditions and the epistemic dimension. The relation between these variables was not significant, X^2 (6, N = 1228) = 6.00, p = .42. A compare column proportions test (Table 5) was performed to investigate the relations between the conditions and the specific processes in the epistemic dimension. This test revealed also no significant differences between the conditions and specific processes in the epistemic dimension.

Table 5

Compare column proportions test of the epistemic dimension

Categories of the epistemic dimension	Intervention Group (N%)	Control Group (N%)
Contribution	15.4% a	12.4% a
Verification	8.3% a	8.6% a
Clarification	5.8% a	5.9% a
Elaboration	14.9% a	17.8% a
Positioning	21.7% a	24.8% a
Regulation	20.0% a	18.4% a
Off-task	13.9% a	12.1% a

Figure 6 displays the occurrences of statements for the intervention group and the control group in the social dimension. The overall findings displayed almost twice as many occurrences of statements on conflict-oriented consensus building in the control group as in the intervention group.

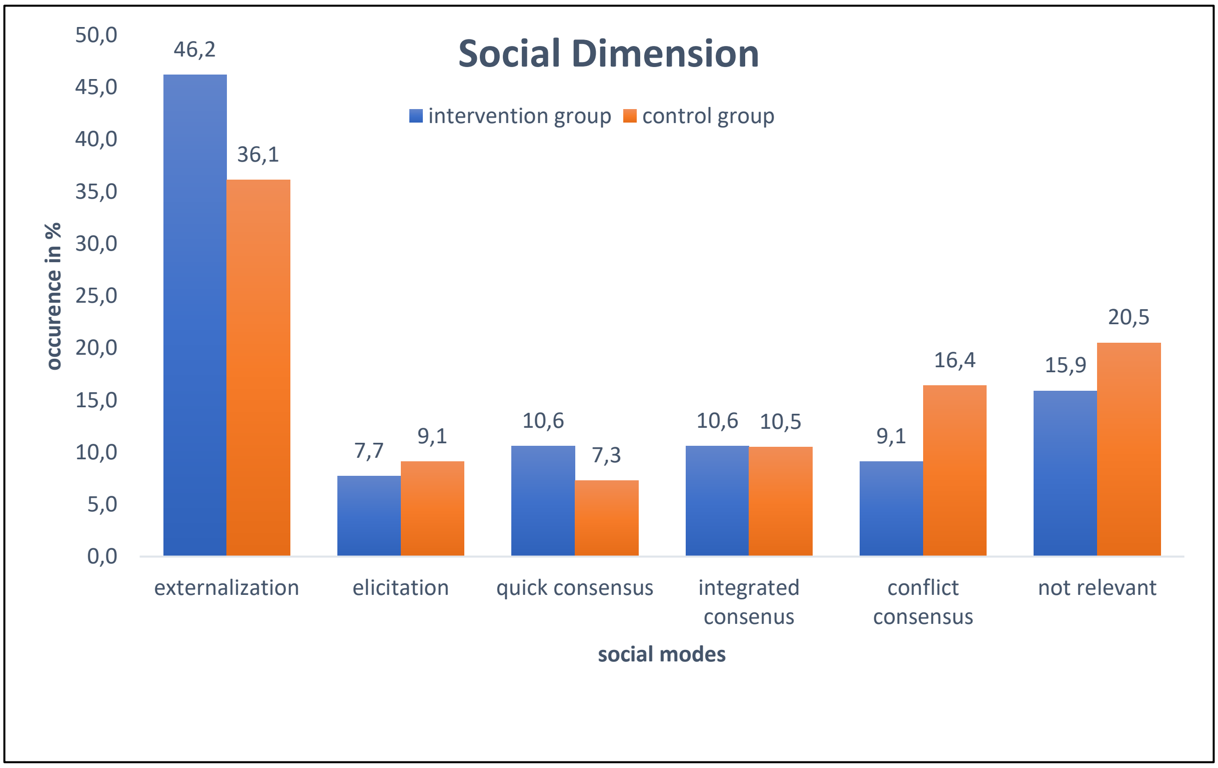

Figure 6. Occurrence (N%) of the six categories in the social dimension.

A Chi-square test of independence was performed to examine the relation between both conditions and the social dimension. The relation between these variables was not significant, X^2 (5, N = 427) = 9.89, p = .078. A compare column proportions test (Table 6) was performed to investigate the relations between the conditions and the specific processes in the social dimension. This test revealed significant differences on two specific processes: externalizations and conflict-oriented consensus building. The intervention group displayed higher occurrences of statements on externalizations than the control group. The control group displayed higher occurrences of statements on conflict-oriented consensus building than the intervention group.

Table 6

Compare column proportions test of the social dimension

Social Modes	Intervention Group (N%)	Control Group (N%)
Externalization	46.2% a	36.1% b
Elicitation	7.7% a	9.1% a
Quick consensus building	10.6% a	7.3% a
Integration oriented consensus building	10.6% a	10.5% a
Conflict oriented consensus building	9.1% a	16.4% b
Not relevant	15.9% a	20.5% a

Content analysis of students' utterances revealed that students in the intervention group argued more about turn-taking than students in the control group (see Excerpt 1). Students in this example were so occupied by the turn-taking process, that the group ignored the correct proposal about air resistance made by student A.

Excerpt 1: arguing about turn-taking (intervention group)

Student	Statement
Student A	I think that this one hits the ground first, because more air resistance is coming here, and less air resistance is coming here. And the one with more air resistance will fall slower.
Student B	Now it's my turn.
Student A	No, her turn.
Student B	No, it's mine...it's clockwise.
Student C	It's clockwise.
Student A	Clockwise...here.

Another interesting finding is that students in the intervention group often shared their contributions, without reacting to each other (see Excerpt 2). Students in this example carefully followed the turn-taking instructions while discussing which paper toy helicopter would stay in the air the longest. All students got a chance to contribute, without interrupting each other. The students also correctly used the sentence starter (I think that...). However, the correct proposals made by students B and C and the incorrect proposal made by student A were ignored by the group. After sharing their contributions, the contradicting perspectives were not discussed. The students just ended the conversation by putting the turn-taking card back on the table.

Excerpt 2: not responding to each other's contributions (intervention group)

Student	Statement
Student A	I think that the helicopter with the flat blades hits the ground first, because it has a different area than the helicopter with folded blades.
Student B	I think because the flat one...like this...the wind gets underneath, like we have seen with the parachute, and the folded one...eh...the wind passes like that. So that's why that one is faster.
Student C	I think that the helicopter with folded blades hits the ground first, because more air pushes against the one with flat blades, so it stays in the air longer.
Student D	I have the same as student B.
Student B	Okay.
Student C	Okay, then put it (the turn-taking card) back.

Content analysis of the utterances showed that students in the control group more often reacted to each other's contributions (see Excerpt 3). Students in this example discussed their hypotheses whether a stuffed animal or a frisbee would hit the ground first. Although not all students equally contributed to the discussion (student D did not contribute in the discussion from the beginning), the students in this group listened and reacted to each other's contributions and together agreed on a hypothesis.

Excerpt 3: responding to each other's contributions (control group)

Student	Statement
Student A	I think the third one is the stuffed animal.
Student B	No, here I think first the...no, I think both, I think both.
Student C	No, because the frisbee will go like this (shows whirling movement with hands).
Student A	Yes, the frisbee.
Student B	The frisbee...of course, it's flat!
Student C	The frisbee is flat and goes like this (shows whirling movement again).
Student B	So, the...

Student D	The stuffed animal.
Student C	So, it is the stuffed animal.
Student A	The stuffed animal.
Student D	Yes, but if you are really bad at throwing frisbees, the frisbee will come down fast though.

The findings indicate that the students in the intervention group, collaborating with a social script, spent more time arguing over turn-taking and less time reacting to each other's contributions than the students in the control group, collaborating without the social script.

4. Discussion and Conclusion

4.1 Discussion and Conclusion

The purpose of this study was to investigate the effects of structured and unstructured collaboration on collaborative IBL with early elementary school students. The overarching research question was, 'What are the effects of structured and unstructured collaboration on collaborative inquiry-based learning in early elementary school students?'. It was hypothesized that structured collaboration leads to a better recall of declarative knowledge, a better procedural knowledge of scientific inquiry processes and a higher quality of group discourse than unstructured collaboration.

The first hypothesis, the effect of structured or unstructured collaboration on the recall of declarative knowledge was measured with the pre- and post-test scores, controlling for age, gender and linguistic section. Based on the results of this study, the hypothesis was not accepted. No main effect of structuring the collaboration process on the recall of declarative knowledge in young elementary students was found in this study. However, there was a significant difference between the students from the Dutch class and the students from the English class. The students from the English class scored higher on the Pre-Test ($M = 4.32$, $SD = 3.06$) than the students from the Dutch class ($M = 1.90$, $SD = 1.89$), indicating a difference in prior knowledge about the lesson topic. Nonetheless, scores on the post-test between the English class ($M = 9.84$, $SD = 3.30$) and the Dutch class ($M = 9.71$, $SD = 3.73$) were not significantly different, confirming the positive effect of IBL on student learning found in the research literature (Pedaste et al., 2015; Schroeder et al., 2007). Hmelo-Silver et al. (2007) argue that extensive research has proven that IBL leads to high learning gains and that disadvantaged students gain most from this approach, because students are more engaged and more motivated to learn when learning through inquiry. Possibly, the inquiry-based approach of the lessons highly engaged students in both conditions and the degree of scaffolding was appropriate for young students, explaining high learning gains for all students, regardless the level of structuredness of the collaboration process. Findings of this study do confirm claims made about the effectiveness of IBL on student learning in past research, as findings indicate a significant difference between the pre-test and post-test for all students. Furthermore, this study also confirms that young elementary students are capable of learning through inquiry, making IBL not only an effective learning strategy for older students, but for young children as well. Samarapungavan et al. (2009) argue that the results of their *Science Learning Assessment* (SLA) also indicate the capability of very young students to understand scientific inquiry. This assessment tool was used to test the second hypothesis in this study.

The second hypothesis, the effect of structured or unstructured collaboration on the procedural knowledge of scientific inquiry processes was measured with the SLA scores, controlling for age, gender and linguistic section. Based on the results of this study, the hypothesis was not accepted. No main effect of structuring the collaboration process on the procedural knowledge of scientific inquiry processes in young elementary students was found in this study. The scaffolding strategies used in the lesson design could possibly also explain these findings. During class discussions the teacher explicitly focused on scientific processes and on teaching students the appropriate scientific vocabulary (e.g. hypothesis, observation, results) to discuss the learning tasks. Scaffolding strategies, such as the science notebook and the sentence starters (e.g. My hypothesis is...), further enforced the understanding of scientific inquiry processes. Although the social script in the intervention group forced all students in this group to verbalize their thoughts using the appropriate scientific vocabulary, as opposed to the students in the control group, the class discussions and scaffolding strategies might have been sufficient for students in the control group to reach a good level of understanding scientific inquiry processes. Findings of this study did indicate a significant difference between the 7-year-old and 8-year-old students on the procedural knowledge of scientific inquiry processes, which is in line with studies on science learning found in the research literature. Jirout and Zimmermann (2015) argue that, although young students' curiosity makes them natural inquirers, science skills, such as experimenting, observing and measuring develop as students get older. A study by Sodian, Zaitchik, and Carey (1991) confirmed this claim. The authors investigated the ability of first and second grade students to choose an empirical test to decide between two conflicting hypotheses. Their findings showed that, although children as young as 6 years old are able do this, the second-grade students outperformed the first-grade students, indicating that science skills develop with age.

In order to get a better understanding of the findings of this study regarding declarative and procedural knowledge, it is important to take a closer look at the collaboration processes itself. The qualitative analysis gives deeper insight into the group discourse.

The third hypothesis, the effect of structured or unstructured collaboration on the quality of group discourse was measured with a qualitative analysis of the group's discourse. The quality of discourse between both conditions was compared through the level of transactivity. This was measured by looking at the number of episodes representing the different social modes (Weinberger & Fischer, 2006). Especially the number of conflict-oriented consensus building episodes was of interest as these episodes promote cognitive growth. Based on the results of this study, the hypothesis was not accepted. The control group even outperformed the intervention group. The level of transactivity in the control group was higher than in the intervention group, as there was a significant difference in the number of conflict-oriented consensus building episodes. However, this difference was not visible in the number of verification, clarification and positioning statements in the epistemic dimension, which, according to De Weerd et al. (2017) are of importance in order to reach the higher levels of transactivity in the social dimension. Verification, clarification and positioning statements did occur more often in the control group than in the intervention group, but the difference with the intervention group was not statistically significant. The higher number of externalizations in the intervention group could be explained by the social script, which forced all students to share their perspective before the group could proceed.

The results of this study are not consistent with most studies on structured and unstructured collaboration found in the research literature. Results in studies on the effect of structured and unstructured collaboration by Saleh et al. (2007) and Aslan (2015) showed higher learning gains and a higher quality of group discourse in the structured collaboration groups. It must be noted though that these studies were performed with older students (upper elementary school) and this raises the question if the effects of structuring collaboration are different for younger students than for older students. Maybe a highly structured collaboration process is not beneficial for young students? Maybe a highly structured social script distracts young students from the learning task? Or maybe young students need more time to practice with a social script, before they can efficiently use it? Lee, Sullivan, and Bers (2013) performed a study on collaboration between young students (Kindergarten) in either a structured or unstructured learning environment. Students in the unstructured learning environment engaged in a higher number of social collaborations with their peers than students in the structured learning environment. The number of empirical studies on structuring collaboration with young children found in the research literature is very limited though. More research on collaborative IBL with young students is needed to answer the questions raised by the findings of this study.

Over-scripting (Dillenbourg, 2002) could also possibly explain the findings of this study. As discussed in the introduction of this paper, rigid collaboration scripts could lead to decreased student motivation. Rummel and Spada (2005) compared the effects on student learning between pairs of psychology and medical students who learned through scripted and unscripted collaborative problem-solving. Although the students in the scripted condition outperformed students in the unscripted condition, and the authors conclude that guiding students in their collaboration process is more effective than having students collaborate freely, they also noticed motivational problems in students in the scripted condition, as they expressed frustration with the script in their conversations. Findings in a study on the collaboration process of 6th grade students by Barron (2003) indicate that collaboration is less successful when peers are unwilling to collaborate or when they argue about turn-taking. Possibly, the social script used in this study has this effect on young elementary students.

During the IBL lessons in this study it was noticed by both the teacher and the researcher that there was less flow in the lessons in the intervention group than in the lessons in the control group, indicating that the natural collaboration processes might have been affected by the script. Content analysis of the utterances showed that students in the intervention group had more equal turns than students in the control group, in which some students hardly interacted with their peers at all. However, the students in the intervention group reacted less to each other's contributions and spent more time arguing about turn-taking. The expected effect of the turn-taking cards in this study (making sure that all students contributed to the group discourse) seemed to interfere with the natural collaboration processes between the students. As illustrated by the excerpts of students' conversations in the findings section of this study, the students focused more on the turn-taking itself and on their own contributions than on listening and responding to their peers' contributions. These examples indicate that the students were occupied with a correct use of the social script at the expense of efficiently collaborating by listening and reacting to each other's contributions. And, as Barron (2003) discovered in her study on collaborative groups, not reacting to peers' contributions leads to a less successful collaboration process. Hmelo-Silver et al. (2007) define collaboration as a 'soft skill' which students need to develop for being life-long learners and for growing up in the 21st century. Although many studies on collaborative learning have been conducted, little research is to be found on the effects of structuring collaborative learning for young elementary students. This study provides some insight into structuring collaboration in IBL for young students, but more research is needed to understand how to teach young elementary students to effectively collaborate in order to achieve higher learning gains and to develop this important 21st century skill.

4.2 Limitations and Implications for Future Research

There are inherent limitations to this study. First, this study has a small sample size of 40 participants. For the quantitative analysis, a larger sample size would have allowed to make more solid inferences about the population, but the qualitative analysis of the students' discourse would have been too time-consuming with a larger sample size. Another limitation was the fact that the participants had to be divided into Dutch- and English-speaking intervention and control groups, as there were not enough pupils in one language section for an adequate sample size. Future research should include a larger sample size and preferably with students who speak the same language, so the participants can be divided over one intervention and one control group.

Another limitation was possibly the structuredness of the social script. The collaboration process in the intervention group in this study, was scripted using turn-taking cards and by giving students explicit interaction rules on how to use the turn-taking cards. Scripting the collaboration process was expected to lead to equal student turns, making sure that all students were engaged, and all students contributed to the group discourse, which in past research has proven to be an effective way to avoid social loafing and to ensure individual accountability and positive interdependence. However, in this study the high level of structuredness of the script might have caused frustration with the young students. Although social loafing did not occur in the intervention group, as all students were forced to contribute to the discussion, students often did not react to each other's contributions and argued about the turn-taking. This raises two questions. The first question is: Maybe the script that was chosen for this study is not effective for young elementary students? There are of course many variations of structuring the collaboration process. This study focused on structuring the collaboration process with turn-taking cards and interaction rules. Future research could include the use of differentiated collaboration scripts to structure the collaboration process, to find out which collaboration scripts are most effective for collaborative inquiry-based learning in early elementary school students. Kollar et al. (2007) explain that collaboration scripts vary in their degree of structuredness and that more research is needed to find out which degree of structuredness is most effective for collaborative learning.

A second question raised by the findings of this study is: Maybe positive effects on learning gains do occur when students have enough time to learn how to use the script effectively? The chosen script could be effective for young students, but students might need more time to get used to the script. Possibly, teaching young students how to use a social script is the solution. In order to avoid social loafing, it is important that all students have the opportunity to contribute to the learning task. The use of a social script avoids social loafing. However, young students might need to learn that this does not mean that they can not react to each other's contributions. Young students might benefit from being trained on how to critically listen and respond to each other. Schraw et al. (2006) came to the same conclusion and claim that collaborative inquiry learning is most effective when students are trained in how to collaborate effectively. The inquiry cycle in this study was limited to two lessons for each group, because of organizational reasons. The lessons had to be taught to four different groups of students and the teacher had to be replaced during that time. If students would have had more time to get used to the collaboration script, they might have been able to use the script more effectively, leading to better results. Future research could include more time for the participants to get used to the collaboration script or could include training sessions on how to use the collaboration script more effectively, before participating in the IBL lessons. This might prevent the participants from arguing about the turn-taking, which distracts them from the lesson content.

As aforementioned, not much empirical research has been conducted on collaborative inquiry-based learning in early elementary students so far. To validate the findings of this study, more research on structuring collaboration in inquiry-based learning in early elementary students is needed.

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Appendix 1 Pre-Test (Post-Test contains identical questions)

Pre-Test Gravity and Air Resistance

Answer the questions below. It is okay if you don't know the answers to all questions or even to any questions. You are going to learn about this later.

1. **What is gravity?**
   - O Gravity is a plant.
   - O Gravity is a force between the Earth and all objects, which speeds up all objects that fall.
   - O Gravity is a force between the Earth and all objects, which slows down all objects that fall.
   - O I don't know.

2. **Which scientist discovered gravity?**
   - O Aristotle
   - O Galileo
   - O Newton
   - O I don't know.

3. **Which scientist believed that heavy objects fall faster than lighter objects?**
   - O Aristotle
   - O Galileo
   - O Newton
   - O I don't know.

4. **Which scientist believed that objects in a free fall hit the ground at the same time?**
   - O Aristotle
   - O Galileo
   - O Newton
   - O I don't know.

5. **From which famous building did Galileo drop two balls with different weights to prove his idea?**
   - O the Eiffel Tower
   - O the Big Ben
   - O the Tower of Pisa
   - O I don't know.

6. **In free fall all objects speed up at the same pace. At what pace is that?**
   O 5 m/s^2 (= 5 meters per second, every second)
   O 9,8 m/s^2
   O 25 m/s^2
   O I don't know

7. **What is air resistance?**
   O Air resistance is a parachute.
   O Air resistance is the same as gravity.
   O Air resistance is a force that slows down falling objects.
   O I don't know.

8. **Look at the picture on the right.**
   Which word could you write next to the blue arrow?
   O parachute
   O gravity
   O air resistance
   O I don't know.

9. **Look at the picture on the right.**
   Which word could you write next to the red arrow?
   O parachute
   O gravity
   O air resistance
   O I don't know.

10. **What happens when you increase (= make larger) the surface area of an object?**
    O The gravity increases.
    O The air resistance increases.
    O Nothing happens.
    O I don't know.

11. **Why do sky divers use parachutes?**
    O A parachute is very light, so it slows down the skydiver.
    O A parachute slows down the sky diver, because it has a large surface area.
    O A parachute is soft, so the sky diver will have a soft landing.
    O I don't know.

12. What is terminal velocity?

O Terminal velocity means that objects fall very fast.

O Terminal velocity means that objects no longer speed up or slow down, but fall at a steady speed.

O Terminal velocity means that objects hit the ground.

O I don't know.

13. When do falling objects reach terminal velocity?

O when gravity and air resistance are the same

O when falling objects hit the ground

O when objects fall from an airplane

O I don't know.

14. I drop a small Lego cube  **and a big Duplo cube**  **at the same time. Which cube will hit the ground first?**

O The Duplo cube is heavier, so it hits the ground first.

O The Lego cube is lighter, so it hits the ground first.

O Both cubes hit the ground at the same time.

O I don't know.

15. I drop a stuffed animal  **and a frisbee** 

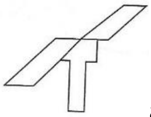
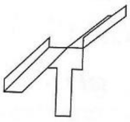
at the same time. Which toy will hit the ground first?

O The stuffed animal hits the ground first.

O The frisbee hits the ground first.

O Both toys hit the ground at the same time.

O I don't know.

16. I make a helicopter with flat blades  **and a helicopter with folded blades.**  **I drop both helicopters at the same time. Which helicopter will stay in the air the longest?**

O The helicopter with flat blades will stay in the air the longest.

O The helicopter with folded blades will stay in the air the longest.

O Both helicopters will hit the ground at the same time.

O I don't know

Appendix 2 Adapted Science Learning Assessment (SLA)

Science Learning Assessment

Read the questions about science and answer them by circling the picture with the right answer.

1. Which of these children is doing science?

Tom plays with Lego.

Eric makes a drawing.

Finn does an experiment.

2. Which of these children is doing science?

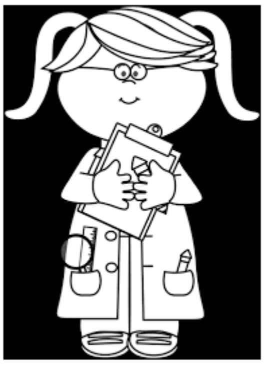
Gina observes a snail.

Jane plays the trumpet.

Kara practices jumping rope.

3. Which of these children is doing science?

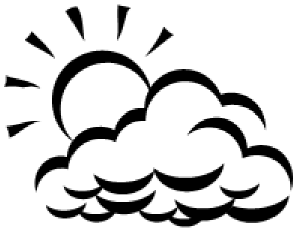
Victor reads a book.



Linda writes her observations in her science notebook.

Tim writes a story.

4. Here are three questions. Which of these is a science question?



Are clouds pretty? Why does it rain? Do you have an umbrella?

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5. Here are three questions. Which of these is a science question?

Can I climb in this tree? Does this tree need water to grow? Is this a nice tree?

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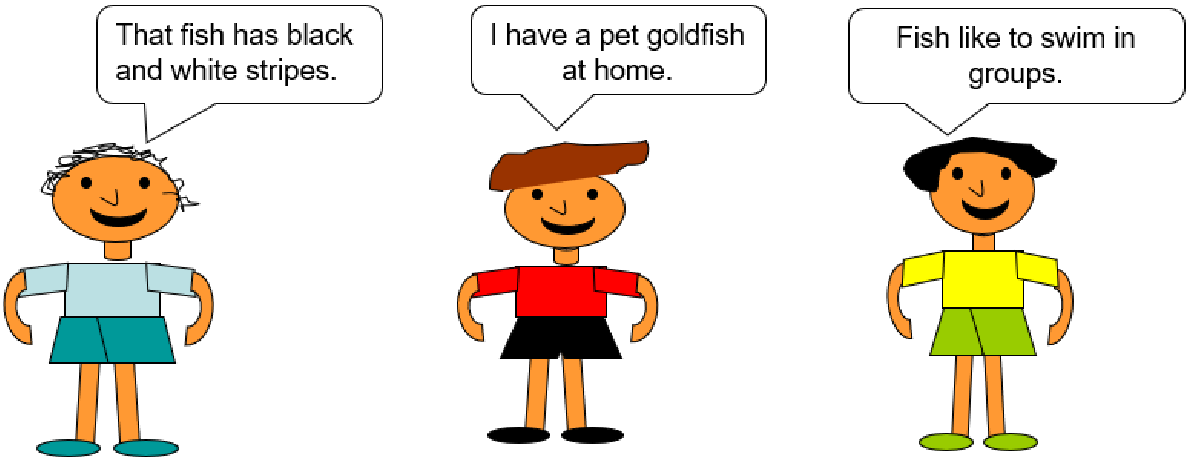
6. Here are three questions. Which of these is a science question?

Why do boats float? Do you like sailing? Why is this sail blue?

7. Each boy said something about a fish. Which of these boys observed the fish in the picture?



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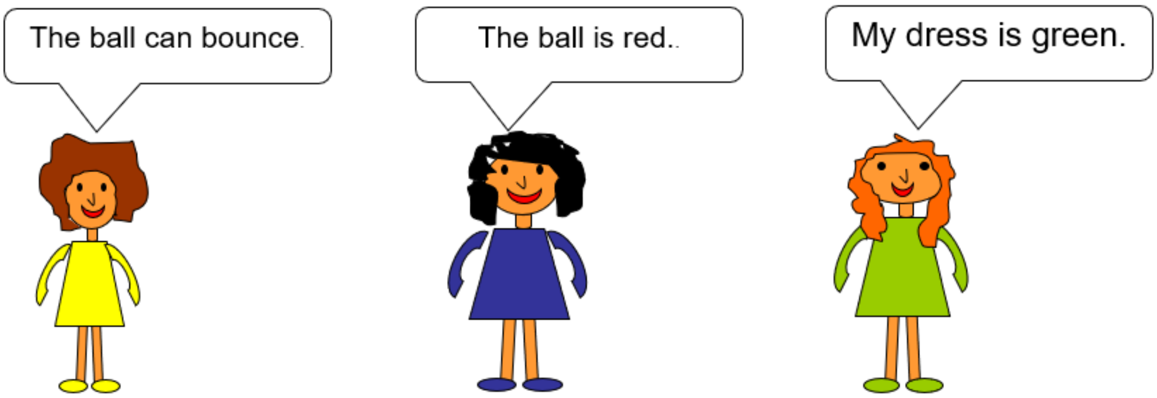
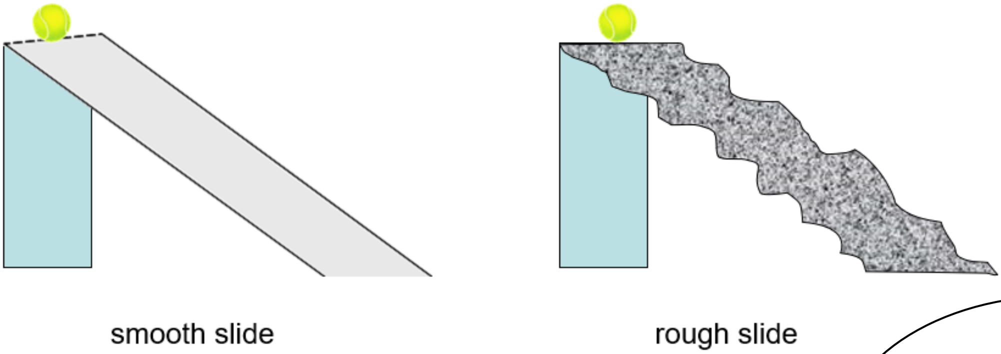
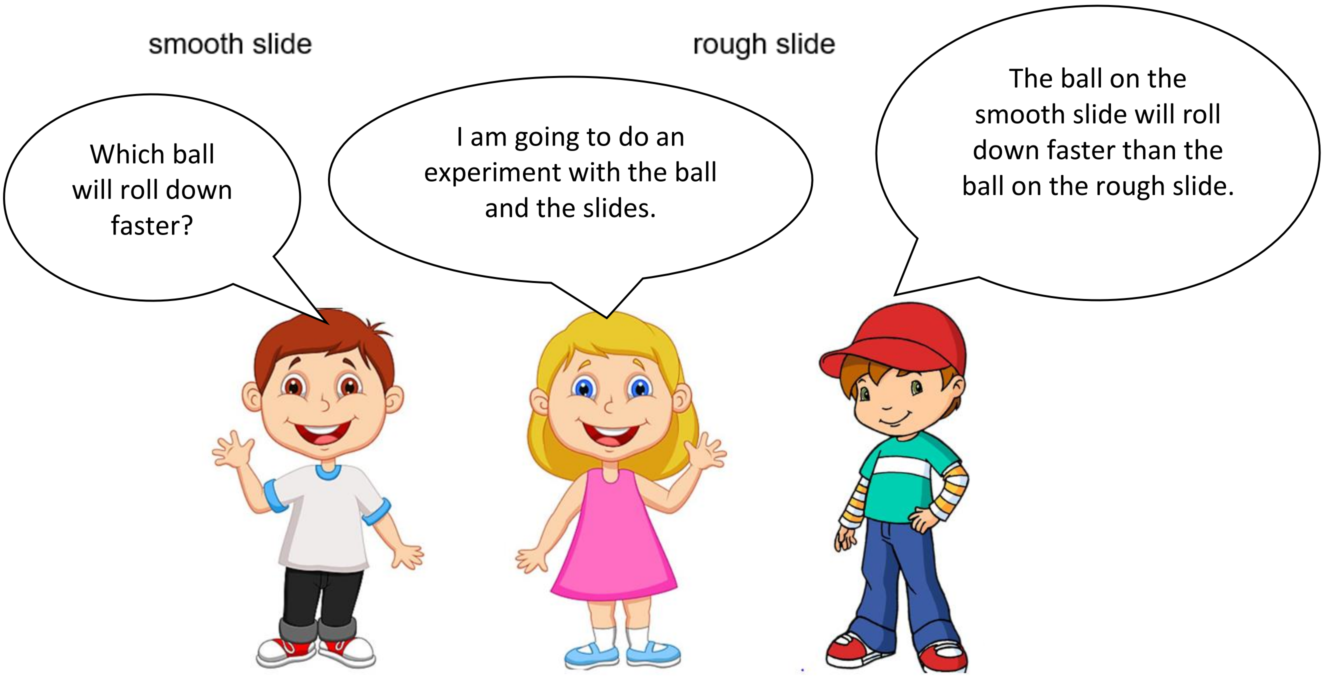
8. One of these girls makes a prediction about the ball: Which one?



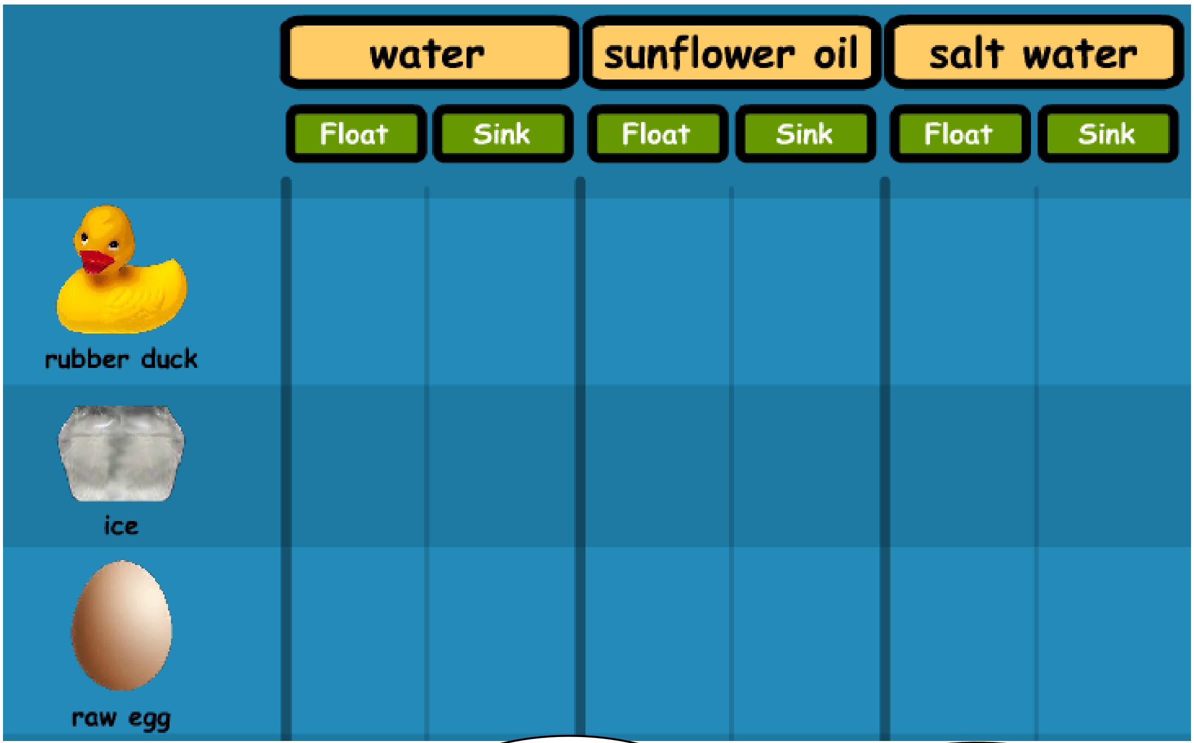
9. Tony, John, and Gina are on the playground. Read what each child says. Which child made a prediction about the teeter totter?

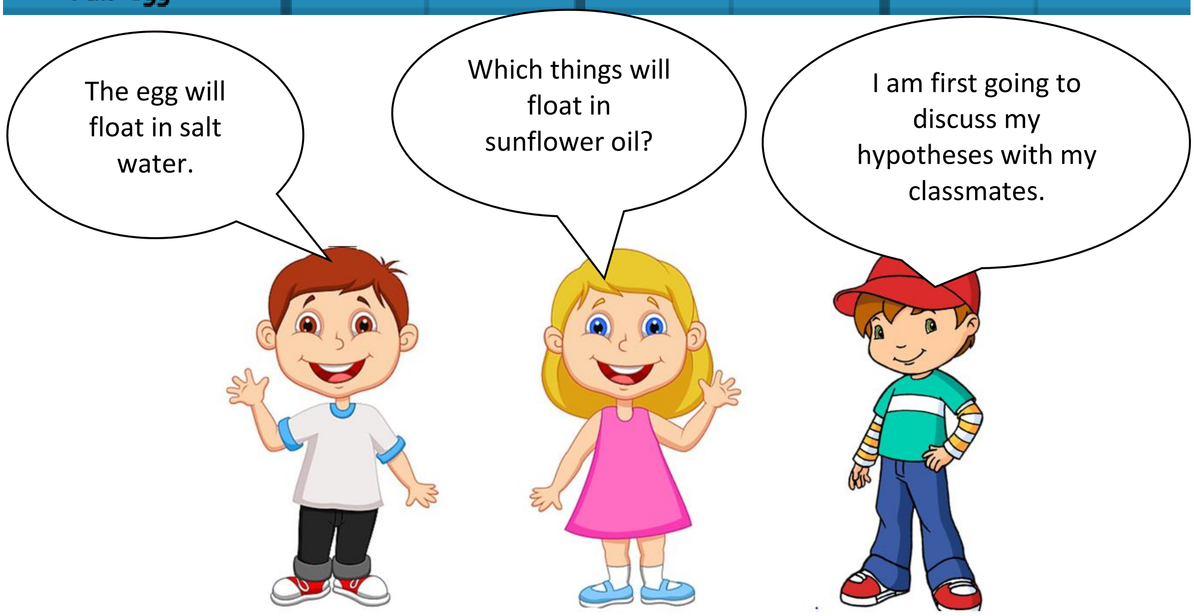
10. Which of these children made a hypothesis about the ball and the slides?





11. Here you see a table in a science notebook from an experiment on floating and sinking. Which of these children gives a hypothesis about this experiment?





12. Here are some tools we use to do science: Which of these can you use to help you remember what you saw ?

Magnifying glass

Stopwatch

Science Notebook

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13. Here are some tools we use to do science: Which of these can you use to look at something very small, such as a bug?

Microscope

Rain Gauge

Digital Scale

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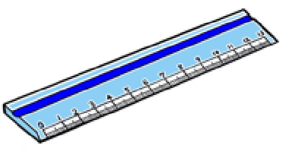
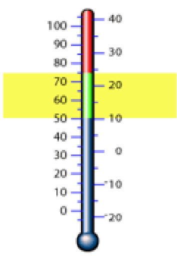
14. Here are some tools we use to do science: Which of these can you use to measure how hot something is?

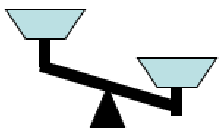
Ruler



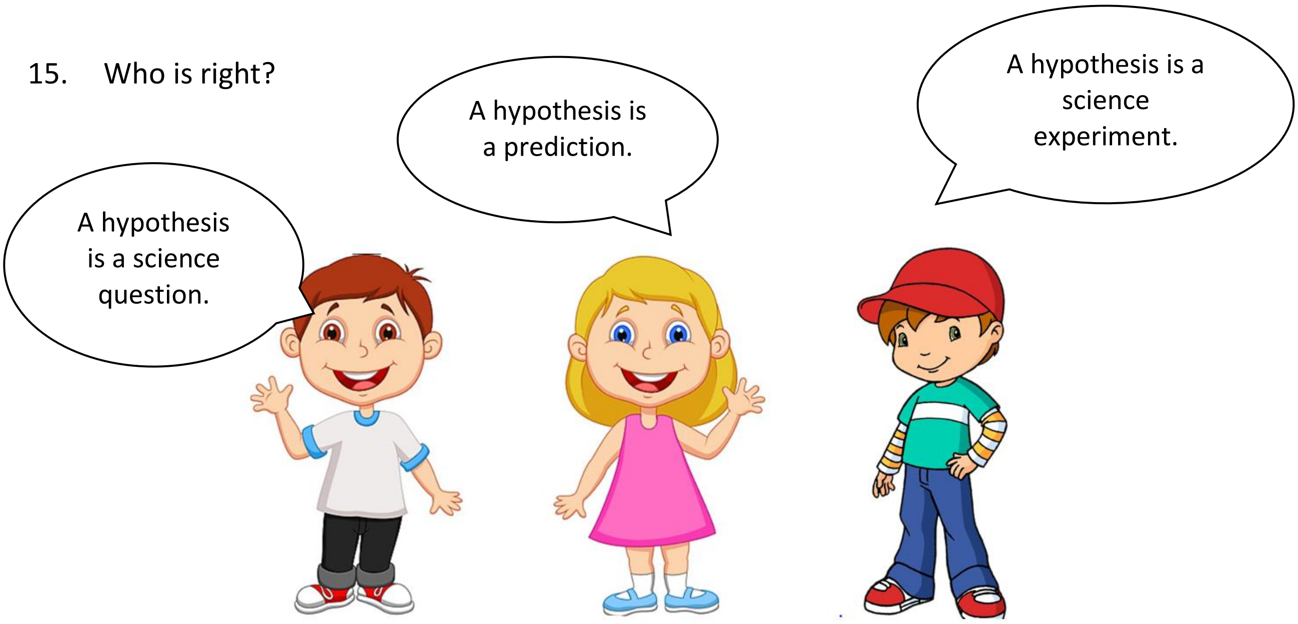
Thermometer



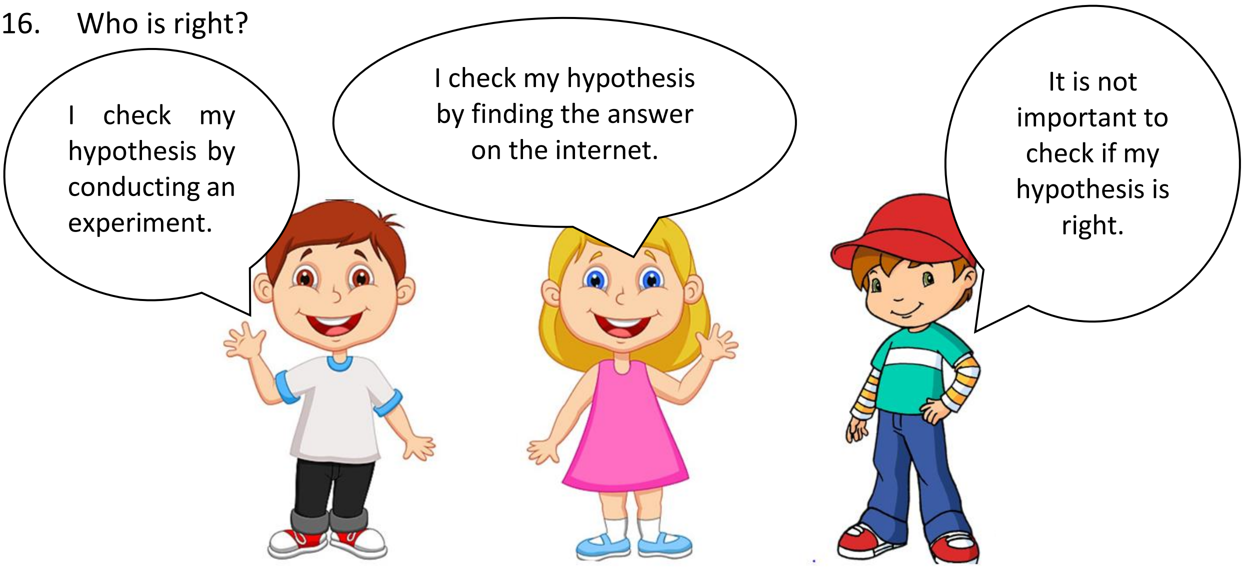
Pan Scales



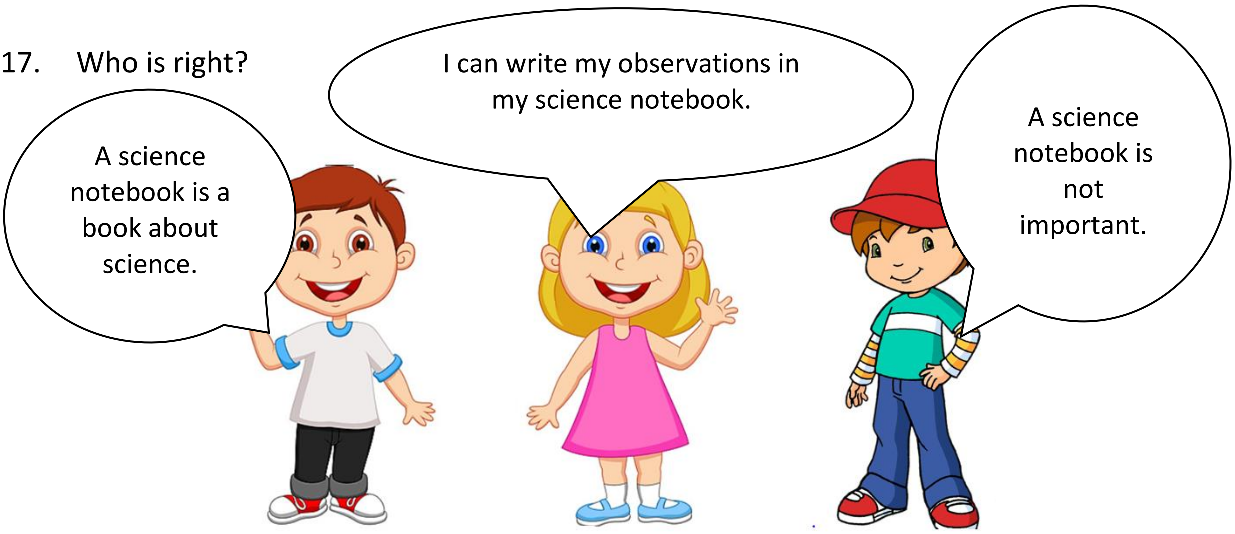
15. Who is right?



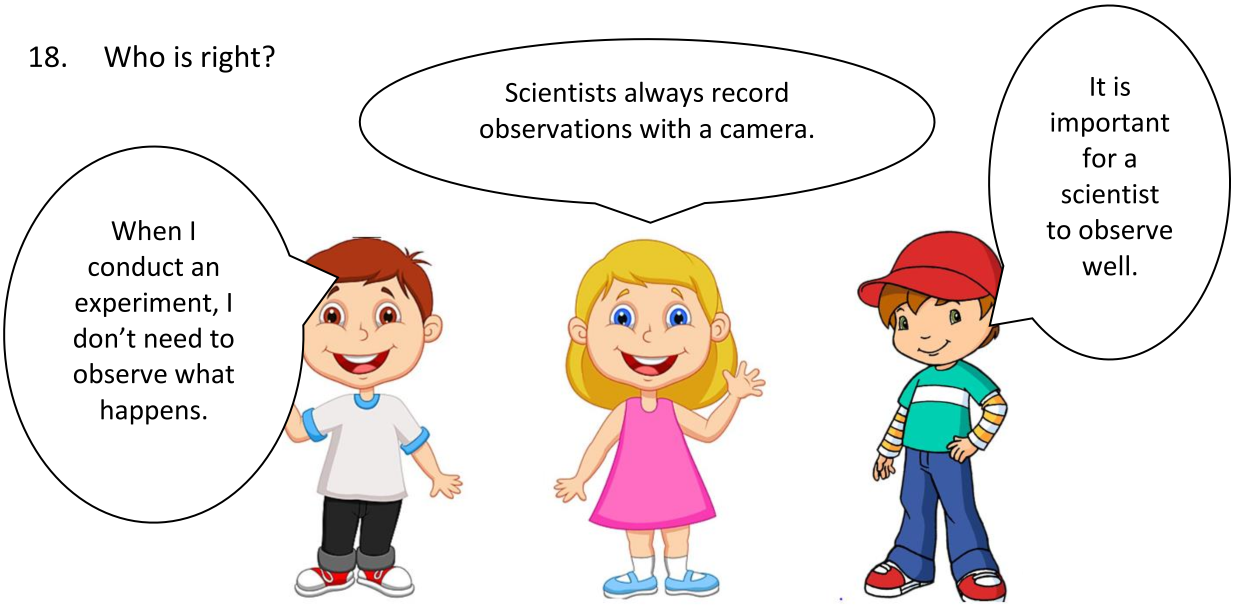
16. Who is right?



17. Who is right?



18. Who is right?



19. Who is right?

20. Who is right?